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(71) Applicant(s)
Hubbell Incorporated

(Incorporated in USA - Connecticut)

574 Derby Milford Road, Orange, Connecticut, United States of America

(72) Inventor(s)
Daniel E Klas
William J Rose
Robert Askins

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(74) Agent and/or Address for Service
Gee and Co
Chancery House, Chancery Lane, LONDON, WC2A 1QU, United Kingdom

(54) Connector for communications systems with cancelled crosstalk

(57) A connector (10) for communications systems has four input terminals (11, 12, 13, 14) and four output terminals (15, 16, 17, 18), each arranged in an ordered array, and a printed circuit electrically coupling each input terminal (11, 12, 13, 14) to the respective output terminal (15, 16, 17, 18), the circuit including four conductive paths (22, 24, 26, 28) between the respective pairs of terminals, the first (22) and third (26) paths being in relatively close proximity and the second (24) and fourth (28) paths being in relatively close proximity. Crosstalk induced across the adjacent connector terminals is thereby cancelled.

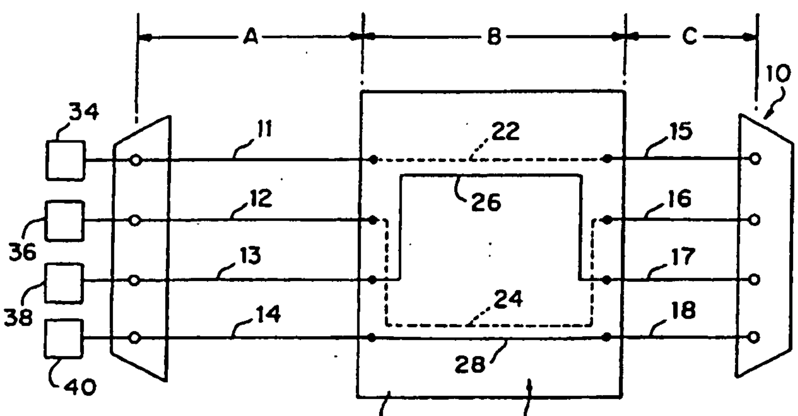

FIG.1

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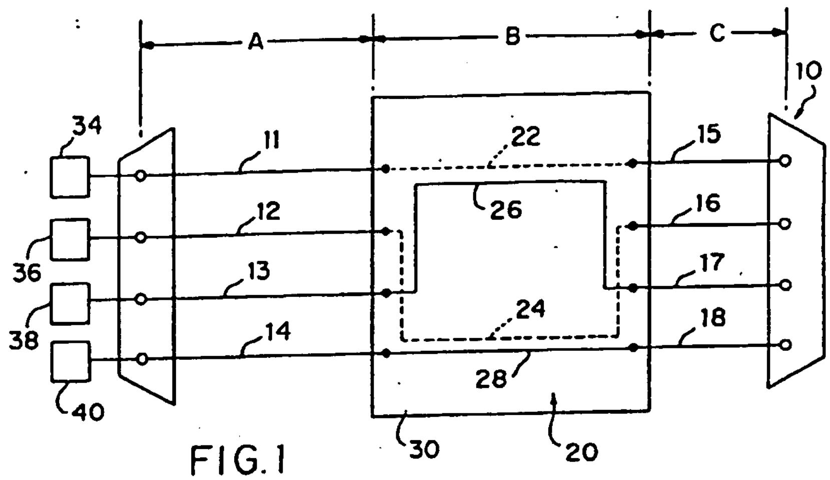

FIG.1

FIG.2

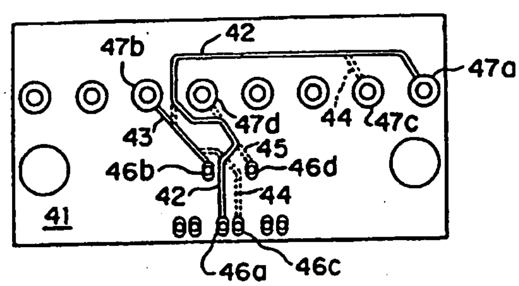

FIG.3

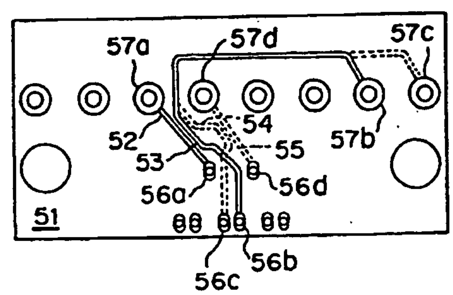

FIG. 4

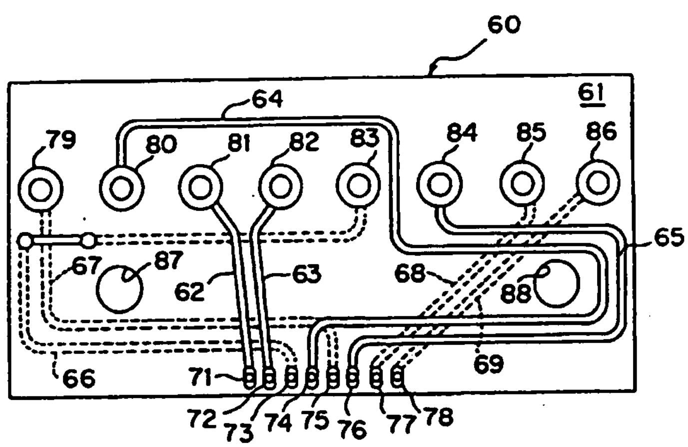
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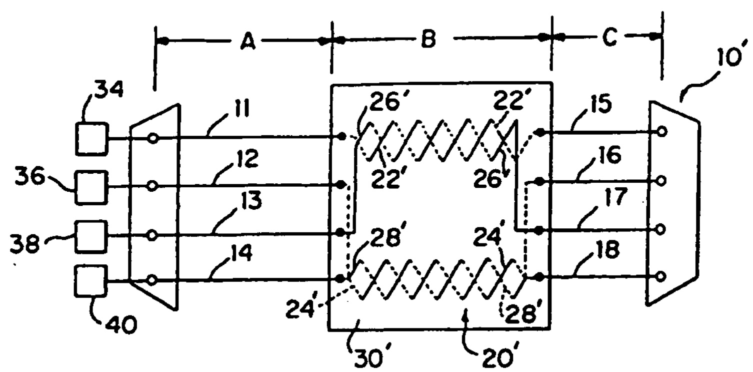
FIG. 5


A
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C
10'
34
36
38
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11
12
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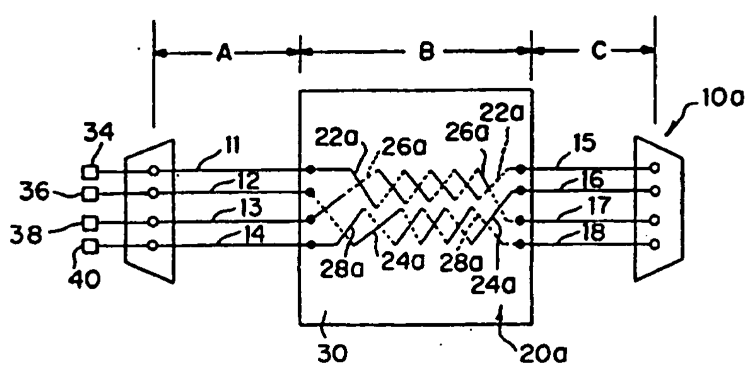
30'
20'

FIG. 6


A
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34
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30
20a

FIG. 7

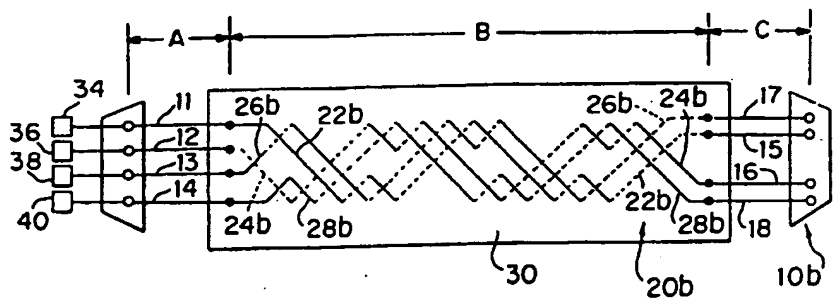


FIG. 8

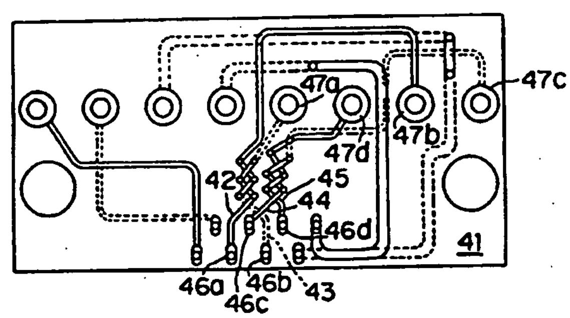
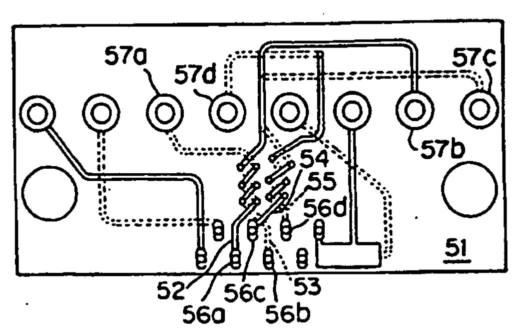


FIG. 9



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Connectors for Communication Systems

The present invention relates to connectors for communication systems in which crosstalk induced between adjacent terminals of the connectors is cancelled. More particularly, the present invention relates to connectors with plural pairs of input and output terminals in which the respective input and output terminals are connected by conductive paths in a manner to cancel the effects of induced crosstalk.

Due to advancements made in telecommunications and data transmission speeds (up to 100MHz) over unshielded twisted pair cables, the connectors (jacks, patch panels, cross-connects, etc.) have become a critical impediment to high performance data transmission at the higher frequencies, i.e. greater than 1MHz. Some performance characteristics (particularly near end crosstalk) degrades beyond acceptable levels at these higher frequencies.

When an electrical signal is carried on a signal line which is in close proximity to another signal line or lines, such as in the case of adjacent pins or terminals in a connector, energy from one signal line can be coupled onto adjacent signal lines by means of the electric field generated by the potential between two signal lines and the magnetic field generated as a result of the changing electric fields. This coupling, whether capacitive or inductive, is called crosstalk when this phenomenon occurs between two or more signal lines.

Crosstalk is a noise signal and degrades the signal-to-noise margin (S/N) of a system. In communications systems, reduced S/N margin results in greater error rates in the information conveyed on a signal line.

One way to overcome this crosstalk problem is to increase the spacing between the signal lines. Another method commonly used is to shield the individual signal lines. However in many cases, the wiring is pre-existing and standards define the geometries and pin definitions for connectors making the necessary changes to such systems cost prohibitive. In the specific case of communications systems using unshielded twisted pair wiring, certain standards defining connector geometries and pinout definitions were created prior to the need for high speed data communications.

Due to advancements made in telecommunications and data transmission speeds (up to 100MHz) over unshielded twisted pair cables, the connectors (jacks, patch panels, cross connects, etc.) have become a critical impediment to high performance data transmission at the higher frequencies, i.e., greater than 1MHz. Some performance characteristics (particularly near end crosstalk) degrades beyond acceptable levels at these higher frequencies.

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These standards have created a large installed base of wiring and connectors and a need for connectors capable of meeting the requirements of today's high speed communications, while maintaining compatibility with the original connectors. The standard connector geometries and pinouts are such that a great deal of crosstalk occurs at these higher signal frequencies.

According to Fourier's theory, when a signal is added to an equal but opposite signal, the two signals cancel each other completely. In unshielded twisted pair wiring, the two wires which are twisted about each other carry identical but opposite signals. These signals are described as being differentially driven. As one signal is driven toward a more positive voltage level, the second signal is driven in the opposite direction or toward a more negative voltage level. These signals being equal but opposite generate fields that are equal but opposite. These equal and opposite fields cancel each other with the result that little crosstalk can occur between a twisted pair and other adjacent signal lines.

In a typical connector used in unshielded twisted pair wiring systems, the signals are conveyed through connector pins or terminals which are parallel to each other for an inch or more, allowing unacceptable levels of crosstalk to occur for today's high speed data signals. These signals are typically in line with each other with the fields from one signal line being coupled onto the one or two immediately adjacent lines. If a noise signal equal, but opposite to, the crosstalk coupled signal is induced onto the affected line, the two induced signals thus coupled will cancel each other. Since the connector carries complementary pairs of signals (i.e. two differentially driven signals of a twisted pair wiring), noise coupled from one line of one pair onto an adjacent line can be

canceled by also coupling an equal amount of "noise" from its complement.

An object of the present invention is to provide a connector for communication systems which will effectively cancel crosstalk induced across the connector terminals.

Another object of the present invention is to provide a connector without net crosstalk between the connector terminals without shielding and without changing the standard connector geometry and pinout definitions.

A further object of the present invention is to provide a connector without crosstalk between the connector terminals which is simple and inexpensive to manufacture and use.

The foregoing objects are basically obtained by a connector for communications systems, comprising first, second, third and fourth input terminals arranged in an ordered array, first, second, third and fourth output terminals arranged in an ordered array, and circuit means for electrically coupling each of the input terminals to the respective output terminal and for cancelling crosstalk induced across the adjacent connector terminals. The circuit means includes first, second, third and fourth conductive paths between the respective input and output terminals. The first and third paths are in relatively close proximity. The second and fourth paths are in relatively close proximity.

By forming the connector in this manner, the crosstalk noise is countered without requiring new equipment and wiring. Instead, the connector design itself eliminates the crosstalk noise, regardless of whether the induced crosstalk results from an inductive coupling by means of

magnetic fields or from a capacitive coupling by means of electric fields, or from a combination of both couplings.

The crosstalk noise is eliminated by, for example, the energy induced onto the second signal line from the first signal line being approximately cancelled by coupling energy to the second signal line from a third signal line in close proximity to the second signal line and carrying a signal equal to, but opposite to, the signal in the first signal line. This operation can be accomplished by either crisscrossing the pins in the connector or by adding a printed wiring board to the connector to allow signals to be run adjacent to each other in a controlled way. By adjusting the width of the printed wiring board traces, the thicknesses of the traces, the separation of adjacent traces and the dielectric constant of the medium between the adjacent traces, the amount of injected crosstalk can be adjusted to cancel that which was injected by the connector pins.

Other objects, advantages and salient features of the present invention will become apparent from the following detailed description, which, taken in conjunction with the annexed drawings, discloses preferred embodiments of the present invention.

Referring to the drawings which form a part of this disclosure:

Figure 1 is a schematic diagram of a connector for communication systems according to a first embodiment the present invention;

Figure 2 is a plan view of a first printed wiring board of a connector according to the first embodiment of the present invention;

Figure 3 is a plan view of a second printed wiring board of a connector according to the first embodiment of the present invention;

Figure 4 is a plan view of a third printed wiring board of a connector according to the first embodiment of the present invention;

Figure 5 is a schematic diagram of a connector for communication systems according to a second embodiment of the present invention;

Figure 6 is a schematic diagram of a connector for communication systems according to a third embodiment of the present invention;

Figure 7 is a schematic diagram of a connector for communication systems according to a fourth embodiment of the present invention;

Figure 8 is a plan view of a printed wiring board of a connector according to the third embodiment of the present invention; and

Figure 9 is a plan view of another printed wiring board of a connector according to the third embodiment of the present invention.

A connector 10 according to the first embodiment the present invention is schematically or diagrammatically illustrated in Figure 1, with the connector divided into an input section A, a circuit section B and an output section C. The circuit section electrically couples the connector input terminals 11, 12, 13 and 14 to the output terminals 15, 16, 17 and 18, respectively, such that crosstalk induced across adjacent terminals in input section A and output section C is cancelled in circuit section B.

The input and output terminals are of conventional designs used in telephone and other communications systems

for such connectors as jacks, patch panels and cross connects. The conventional details of the connector in input section A and output section C are not described in detail. Suitable connectors are disclosed in U.S. Patent No. 4,648,678 to Archer and U.S. Patent No. 5,061,029 to Bolick, the subject matter of each patent being incorporated herein by reference.

The circuit section B comprises a printed wiring board 20 with four printed circuit traces or conductive paths 22, 24, 26 and 28 printed on a substrate 30. Trace 22 extends between and connects input terminal 11 and output terminal 15. Trace 24 extends between and connects input terminal 12 and output terminal 16. Trace 26 extends between and connects input terminal 13 and output terminal 17. Trace 28 extends between an connects input terminal 14 and output terminal 18.

In circuit board 20, traces 22 and 26 are in close proximity to each other inducing crosstalk therebetween, while traces 24 and 28 are in close proximity to each other inducing crosstalk therebetween. Traces 22 and 26 are substantially spaced from traces 24 and 28 to minimize induced crosstalk between such two pairs in circuit board 20.

In input section A and output section C, the proximity of adjacent terminals induces crosstalk between the adjacent terminals. Specifically, crosstalk is induced in terminal 11 from terminal 12, in terminal 12 from terminals 11 and 13, in terminal 13 from terminals 12 and 14, in terminal 14 from terminal 13, in terminal 15 from terminal 16, in terminal 16 from terminals 15 and 17, in terminal 17 from terminals 16 and 18, and in terminal 18 from terminal 17. The spacing between the other or non-adjacent terminals is adequate to minimize crosstalk between the other or non-adjacent terminal pairs.

In a communications system, terminals 11, 12, 13, and 14 are connected to signal sources 34, 36, 38 and 40, respectively. The signals from sources 34 and 40 are equal and opposite (i.e., differently driven) to each other. The signals from sources 36 and 38 are equal and opposite to each other. With the application of these two pairs of opposite or differently driven signals, the crosstalk induced in printed wiring board 20 in circuit section B tends to cancel the crosstalk induced across and between the respective input and output terminals in the input and output sections A and B of the connector.

The length and separation of traces 22, 26, 28 and 30, the thickness and width of each trace, the thickness of substrate 30 (assuming traces are provided on both sides of the substrate), and the dielectric constant of the printed wiring board can be adjusted. With appropriate adjustment of those factors, the crosstalk signals induced between traces 22 and 26 and between traces 24 and 28 can be controlled to cancel, at least approximately, the effects of the induced signals or crosstalk resulting from the proximity of the terminals in input section A and output section C. The factors can also be adjusted to compensate for wiring crosstalk.

The formulas for determining characteristic impedance to estimate crosstalk are presented in Handbook of Analog Circuit Design by Dennis L. Feucht, Academic Press, Inc., Harcourt Brace Javanovich, Publishers, 1990, pp. 387-393, the subject matter of which is incorporated herein by reference, and include the following:

For twisted pair wiring

$$Z_o = \frac{120\ \Omega}{\sqrt{\varepsilon_r}} \ln\left(\frac{h}{d}\right)$$

o

where Z_o = characteristic impedance
ε_r = dielectric constant
h = distance between conductor centers
d = conductor diameter

For traces extending side-by-side

$$Z_n = \frac{120\ \Omega}{\sqrt{\varepsilon_r}} \ln\left(\frac{\pi h}{w+d}\right), \text{ for } w >> d$$

where Z_n = characteristic impedance
ε_r = dieletric constant
h = edge to edge spacing of traces
w = trace width
d = trace thickness

For traces on opposite sides of a printed wiring or circuit board

$$Z_n = \frac{377\ \Omega}{\sqrt{\varepsilon_r}} \left(\frac{h}{w}\right), \text{ for } w >> h >> d$$

where

Z_n = characteristic impedance
ε_r = dielectric constant
w = trace width
h = board thickness
d = trace thickness

The circuit section which will compensate for terminal crosstalk can also comprise wiring, in lieu of the printed circuit board, if the routing of the wire is appropriately controlled. Alternatively, the rerouting of the conductive paths between the respective input and output terminals can be achieved using portions of the connector terminals themselves between the male and female connection portions thereof.

Although the schematic of Figure 1 shows only two pairs of terminals and traces, any number of pairs can be provided.

Figure 2 illustrates a printed wiring board with an over/under energy transfer mode. In this mode, substrate 41 has conductive traces 42 and 43 on one side and conductive traces 44 and 45 on the opposite side between terminal connection points 46 a-d and 47 a-d. Portions of traces 42 directly overlie portions of trace 45, while portions of trace 43 directly overlie portions of trace 44. Trace 42 extends between points 46a and 47a. Trace 43 extends between points 46b and 47b. Trace 44 extends between points 46c and 47c. Trace 45 extends between points 46d and 47d.

Figure 3 illustrates a printed wiring board with a side-by-side energy transfer mode. In this mode, substrate 51 has conductive traces 52 and 53 on one side and conductive traces 54 and 55 on the opposite side between terminal connection points 56 a-d and 57 a-d. A portion of trace 52 is slightly laterally offset from a portion of trace 53, while a portion of trace 54 is slightly laterally offset from a portion of trace 55. Trace 52 extends between points 56a and 57a. Trace 53 extends between points 56b and 57b. Trace 54 extends between points 56c and 57c. Trace 55 extends between points 56d and 57d.

Figure 4 illustrates a printed wiring board 60 for a connector known as a keystone jack to be operated at a 20 MHz frequency range. This board includes a substrate 61 with conductive traces 62, 63, 64 and 65 on one side and conductive traces 66, 67, 68 and 69 on the opposite side extending between terminal points or pads 70 - 86. Trace 62 extends between points 71 and 81. Trace 63 extends between points 72 and 82. Trace 64 extends between points 74 and 80. Trace 65 extends between points 76 and 84.